

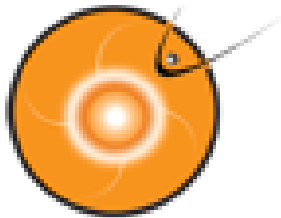
Community Coordinated Modeling Center



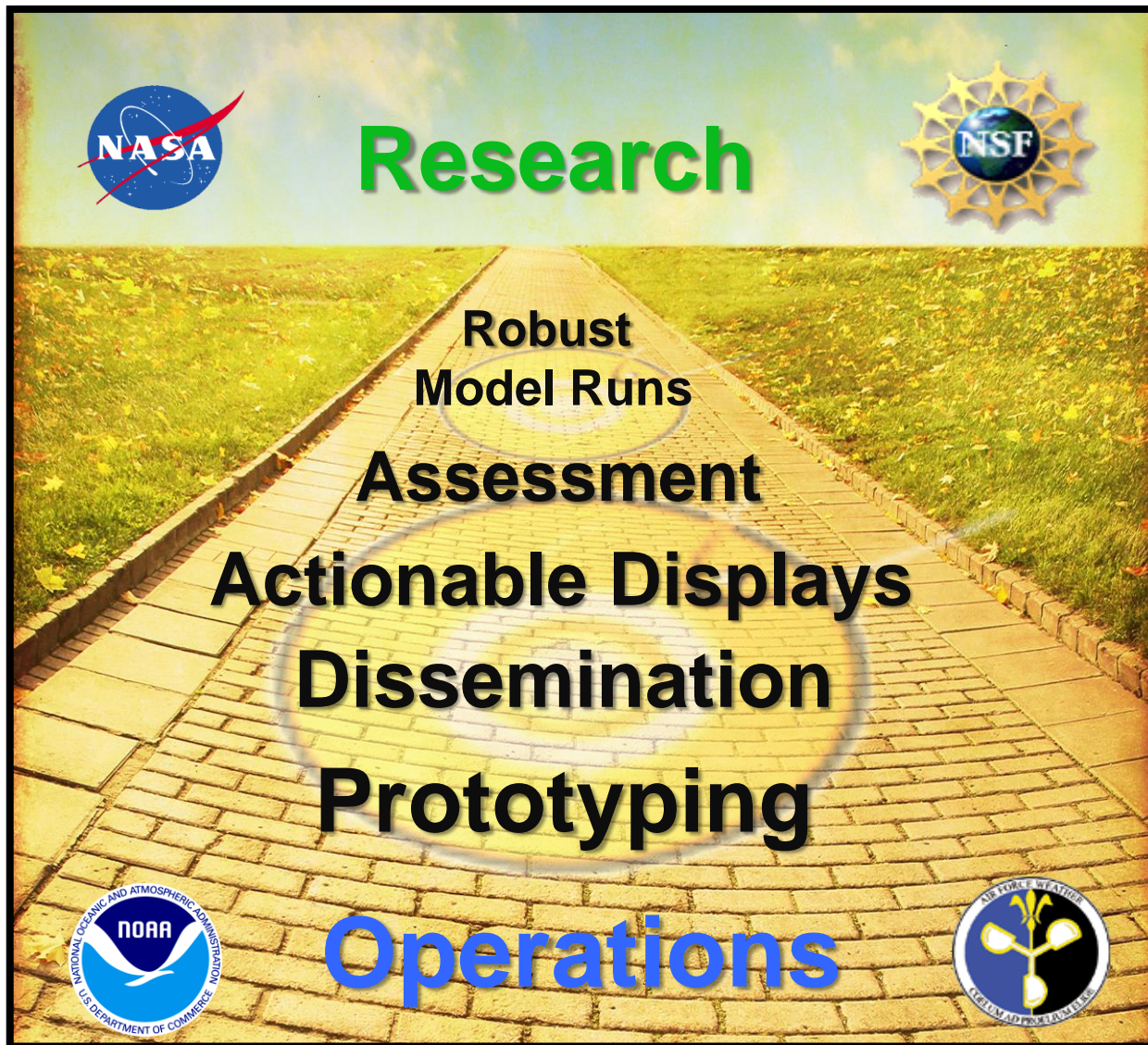
Community Coordinated Assessment and Rapid Implementation of Space Weather Analysis and Forecasting Capabilities

M. Kuznetsova & CCMC Team

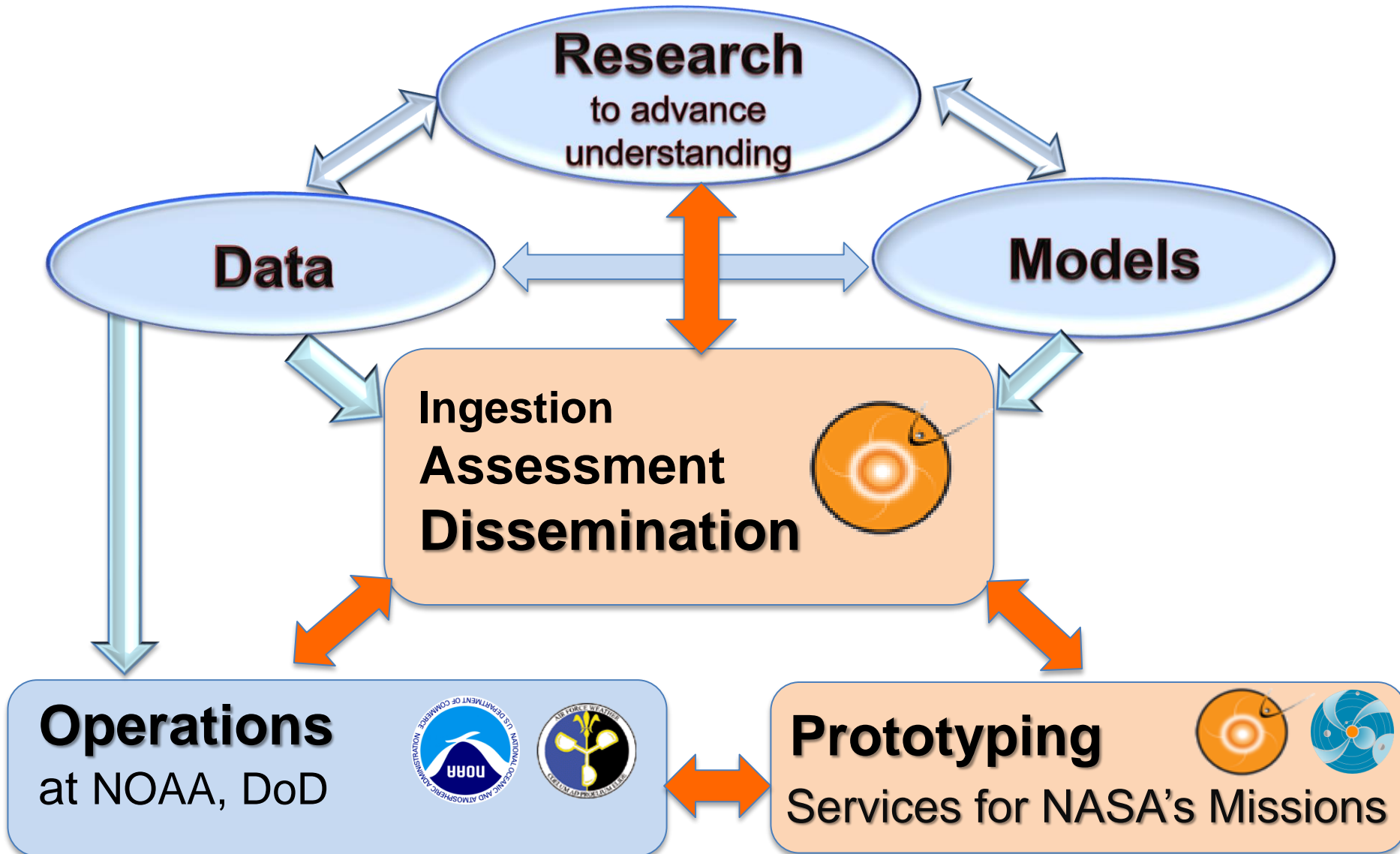
MODELS • DATA • TOOLS • DATABASES • SYSTEMS • SERVICES



CCMC Pioneered the Path from Research 2 Operations



The CCMC as a Hub for Collaborative Advancing of Space Weather Predictive Capability System

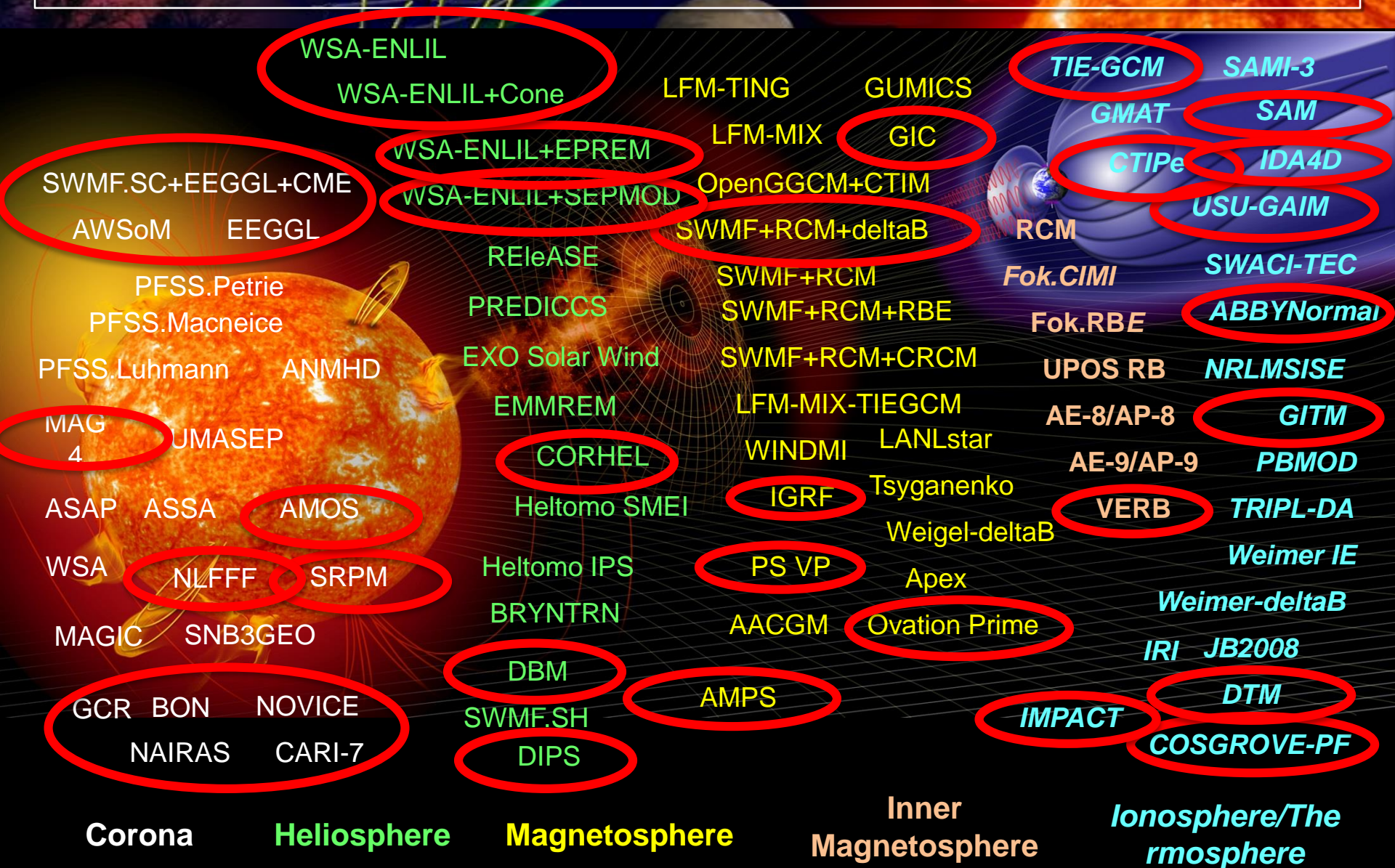


Corona **Heliosphere** **Magnetosphere** **Inner Magnetosphere** **Ionosphere/The rmosphere**

Models shown in the diagram include:

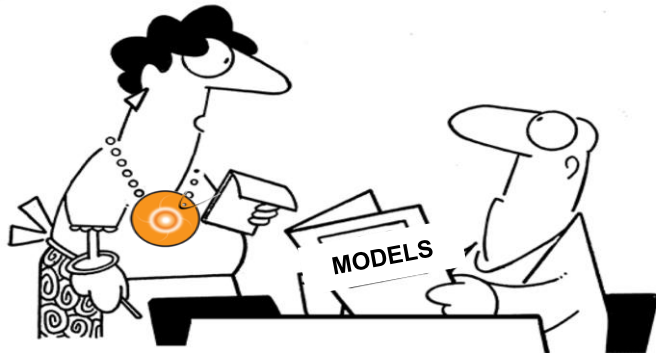
- Corona:** WSA-ENLIL, WSA-ENLIL+Cone, WSA-ENLIL+EPREM, WSA-ENLIL+SEPMOD, REleASE, PREDICCS, EXO Solar Wind, EMMREM, CORHEL, Heltomo SMEI, Heltomo IPS, BRYNTRN, DBM, SWMF.SH, DIPS, GCR, BON, NOVICE, NAIKAS, CARI-7, WSA, NLFFF, SRPM, MAGIC, SNB3GEO, ASAP, ASSA, AMOS, PFSS.Luhmann, ANMHD, MAG 4, UMASEP, PFSS.Petrie, PFSS.Macneice, AWSOM, EEGGL, SWMF.SC+EEGGL+CME.
- Heliosphere:** LFM-TING, LFM-MIX, GUMICS, GIC, OpenGGCM+CTIM, SWMF+RCM+deltaB, SWMF+RCM, SWMF+RCM+RBE, SWMF+RCM+CRCM, LFM-MIX-TIEGCM, WINDMI, IGRF, PS VP, AACGM, AMPS, TIE-GCM, GMAT, CTIPe, RCM, Fok.CIMI, Fok.RBE, UPOS RB, AE-8/AP-8, AE-9/AP-9, VERB, TRIPL-DA, Weimer IE, Weimer-deltaB, IRI, JB2008, DTM, COSGROVE-PF, IMPACT.
- Magnetosphere:** TIE-GCM, SAMI-3, GMAT, SAM, IDA4D, USU-GAIM, SWACI-TEC, ABBYNorma, NRLMSISE, GITM, PBMOD, Weimer IE, Weimer-deltaB, IRI, JB2008, DTM, COSGROVE-PF, IMPACT.
- Inner Magnetosphere:** TIE-GCM, SAMI-3, GMAT, SAM, IDA4D, USU-GAIM, SWACI-TEC, ABBYNorma, NRLMSISE, GITM, PBMOD, Weimer IE, Weimer-deltaB, IRI, JB2008, DTM, COSGROVE-PF, IMPACT.
- Ionosphere/The rmosphere:** TIE-GCM, SAMI-3, GMAT, SAM, IDA4D, USU-GAIM, SWACI-TEC, ABBYNorma, NRLMSISE, GITM, PBMOD, Weimer IE, Weimer-deltaB, IRI, JB2008, DTM, COSGROVE-PF, IMPACT.

Expanding Collection Of Models at CCMC: > 80 New + Upgrades 2014-2016





CCMC Web-Based Signature Services

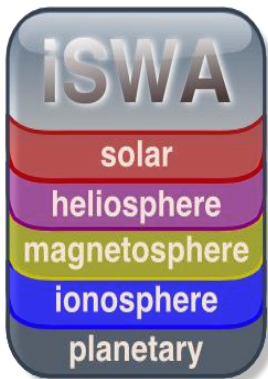


Runs-on-Request System

An interactive system to serve advanced models to the international research community

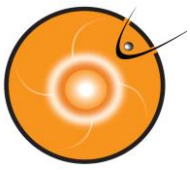
- Support advancing knowledge and understanding
- Maximize return on investment into model development

Integrated Space Weather Analysis System (iSWA)

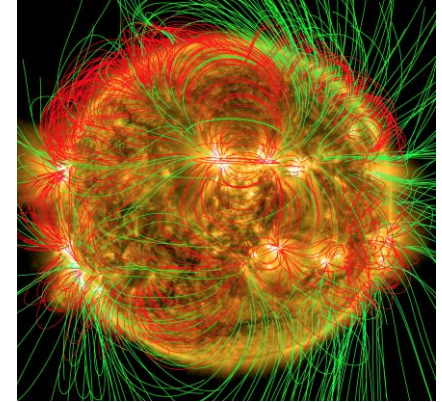
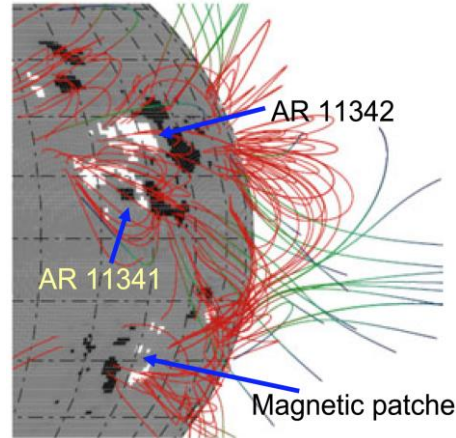
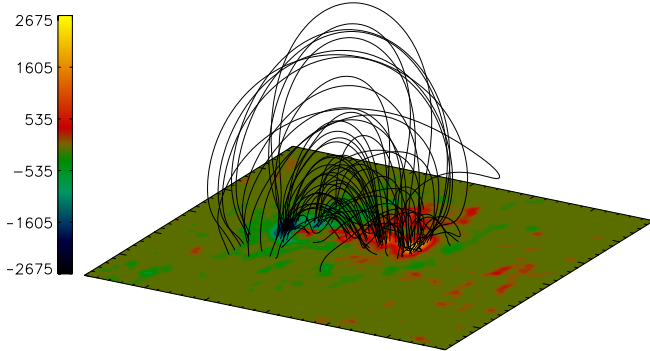


A system for real-time space environment monitoring, event analysis, education and training.

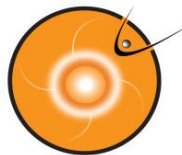
- Real-Time & Historical Model + Observational Data
- Actionable Products. Web Services
- User Configurable, Interactive Displays



Non-Linear Force Free Model

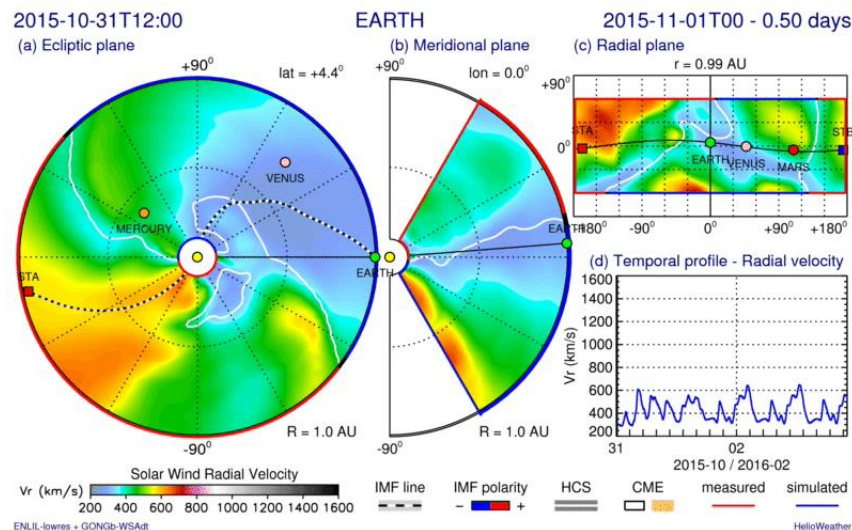


- Designed to study energy and helicity build up in flaring active regions.
- Input SDO/HMI vector magnetograms
- Cartesian grid version available for use now
 - <http://ccmc.gsfc.nasa.gov/requests/SH/NLFF>
- Spherical & Global Grid versions – soon (June/July)



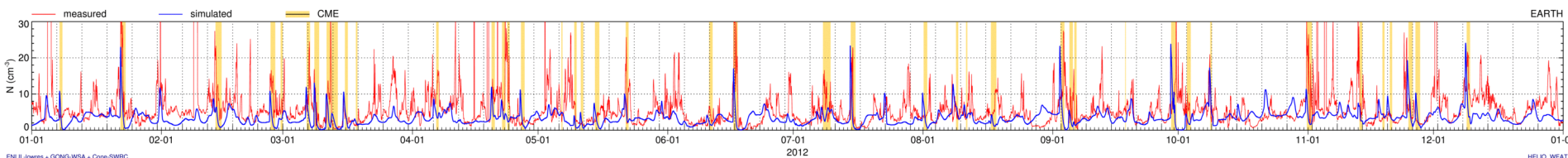
Towards Time-Dependent Magnetograms

- New approaches to time evolving global photospheric field
 - 1 – Time interpolating WSA output based on hourly GONG synoptic magnetograms (**Odstrcil**)
 - 2 – ADAPT (**Arge and Henney**)



WSA-Enlil 2.8f is installed and is offered for Runs-on-Requests.

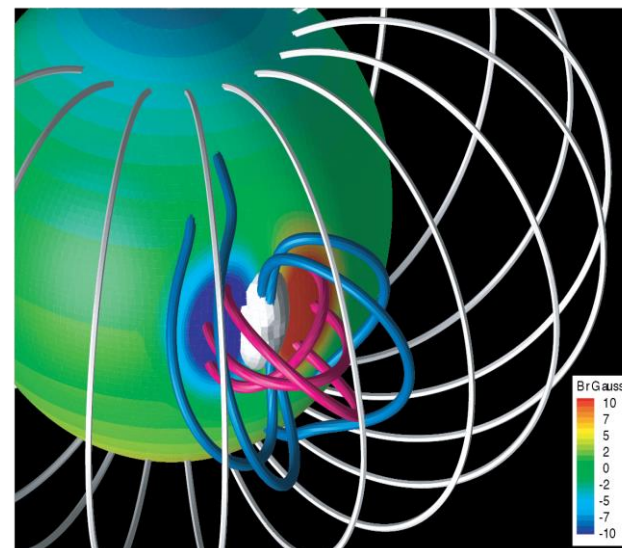
Simulations with time-dependent magnetograms are evaluated and available for special requests. Real-time implementation is coming soon.



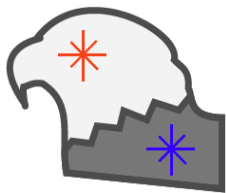


SWMF/AWSoM-R CME Modeling from Low Corona

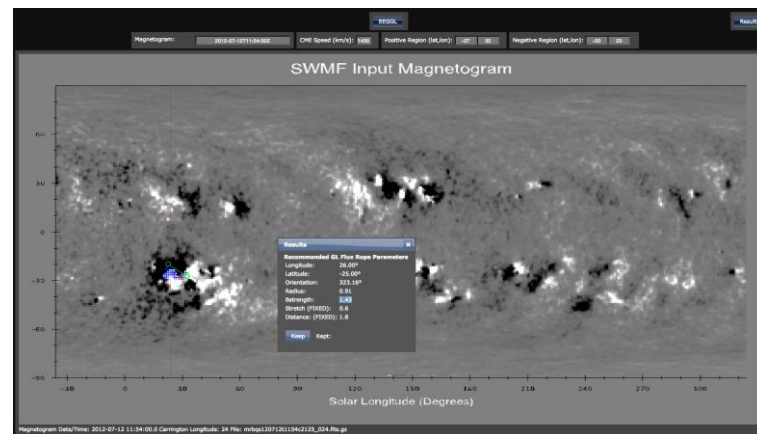
- A new **SWMF/AWSoM-R** coronal model incorporates semi-analytical **Threaded-Field-Line model** for the low solar corona ($1 - 1.1 R_s$)
- Speed up coronal simulations on factor of 100
- To initiate CME: magnetic flux rope superimposed on the background.



EEGGL Eruption Event Generator (Gibson & Low)



Use synoptic magnetograms to define location and orientation of CME flux rope.



Modeler: I. Sokolov, U. of Michigan

CCMC: A.Taktakishvili, R. Mullinix



Towards coupled heliosphere and SEP models

SEP MODELS

SEPMOD

EPREM

SWMF: FLAMPA

SWMF: Kota SEP

SOLAR-HELIOSPHERE
MHD MODELS

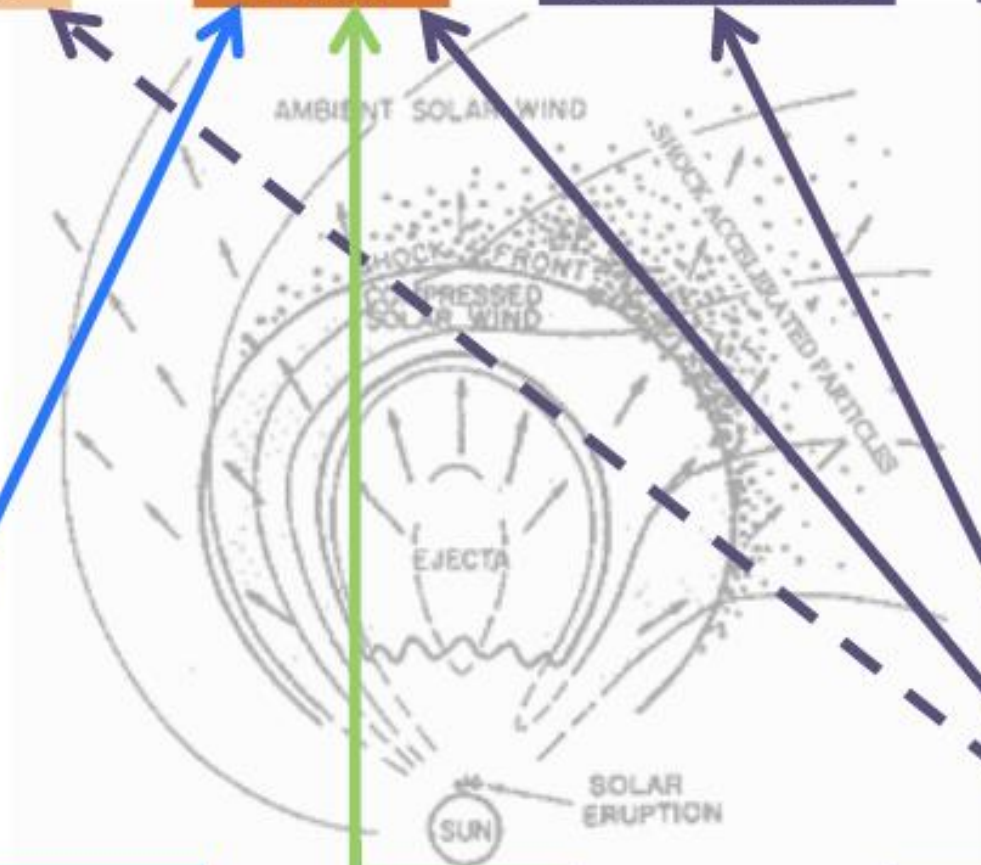
WSA-ENLIL+Cone
Hydrodynamic CME

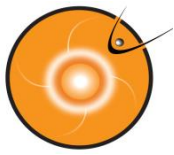
CORHEL

Flux Rope CME (Titov-Demoulin, Gibson-Low)

SWMF: AWSoM-R

Modelers: N. Arge, D. Odstrcil, J. Luhmann, J. Linker, N.Schwadron, M. Gorby, I.Sokolov

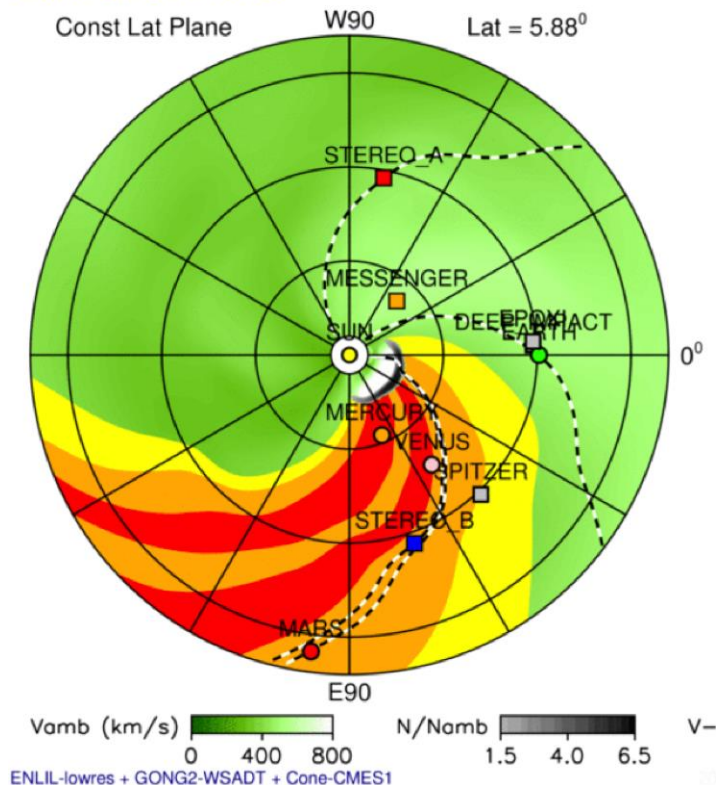




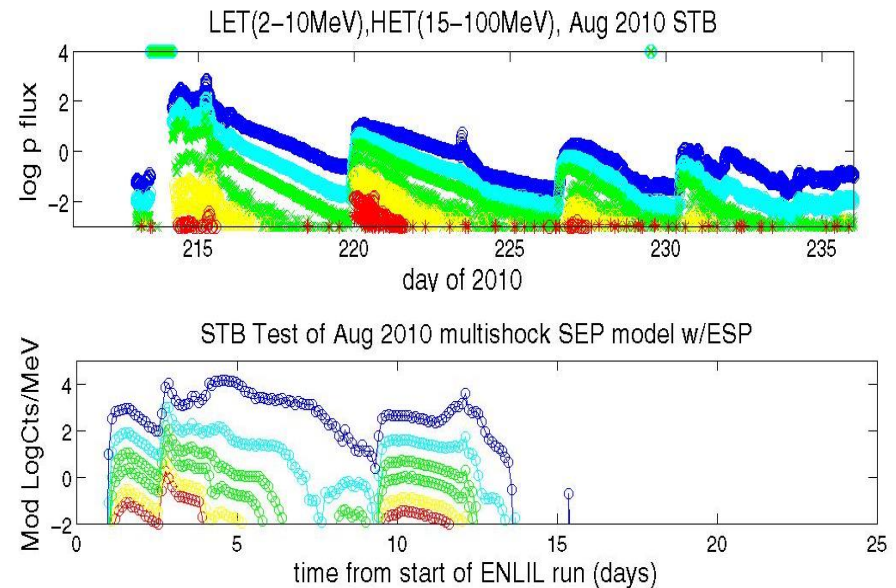
Coupled SEP modeling at the CCMC *WSA-Enlil+SEPMOD*

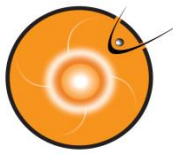
CCMC is facilitating first steps to couple **WSA-ENLIL** with **SEPMOD**
(with model developers **D. Odstrcil** and **J. Luhmann**)

2010-08-01T19:00



SEPMOD at STEREO B

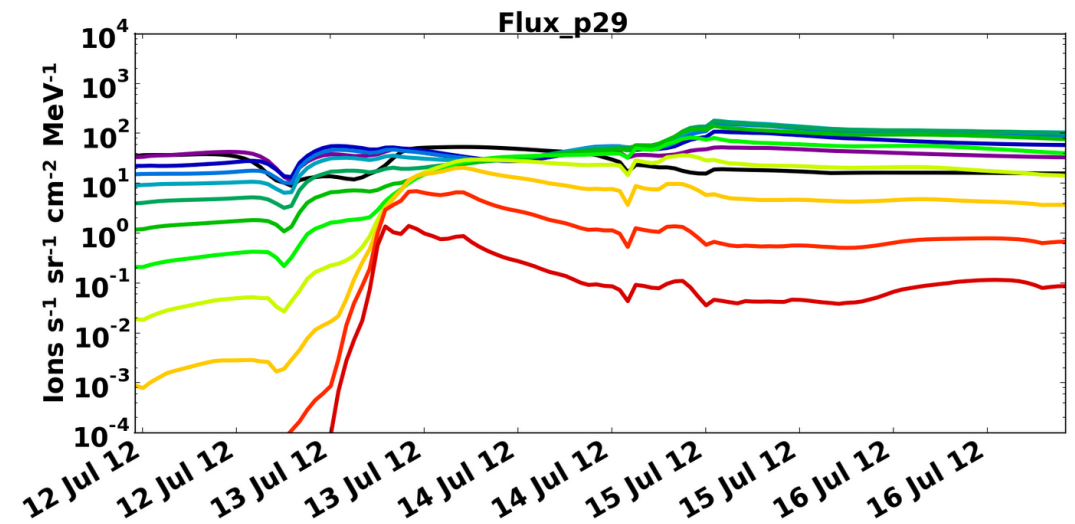
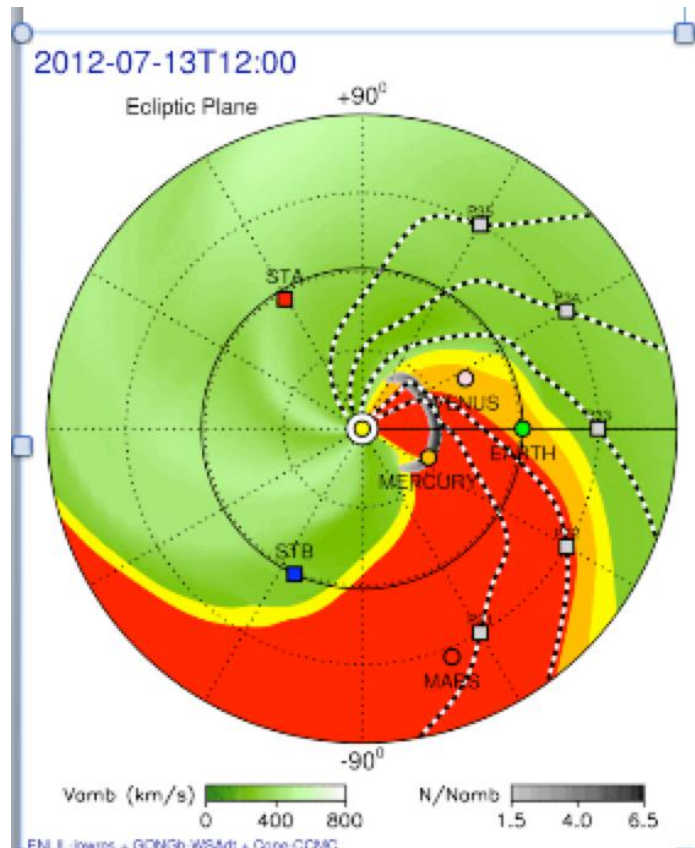


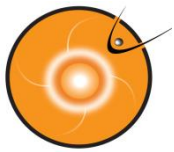


Coupled SEP modeling at the CCMC

WSA+Enlil+EPREM

CCMC is facilitating first steps to couple **WSA-ENLIL** with **EPREM**
(with model developers **D. Odstrcil**, **N. Schwadron** and **M. Gorby**)





Connecting Space Environment to Space Weather Impacts: Radiation Effects

❑ NOVICE

- ❑ Radiation effect code for spacecraft and/or component in complex geometries

❑ NAIRAS (Nowcast of Atmospheric Ionizing Radiation System)

- ❑ Models and assesses radiation exposure levels for aviation from GCRs and SEPs

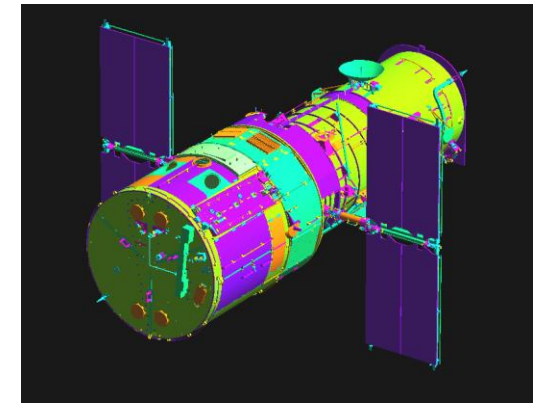
❑ CARI-7

- ❑ Calculates radiation dose from GCRs received by airline passengers/crews

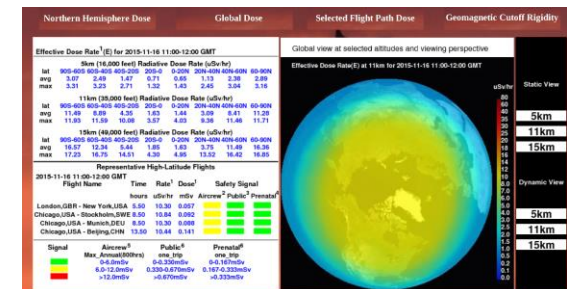
❑ Badhwar-O'Neill (BON) 2014 GCR model

- ❑ Latest Badhwar-O'Neill model of Galactic Cosmic Rays

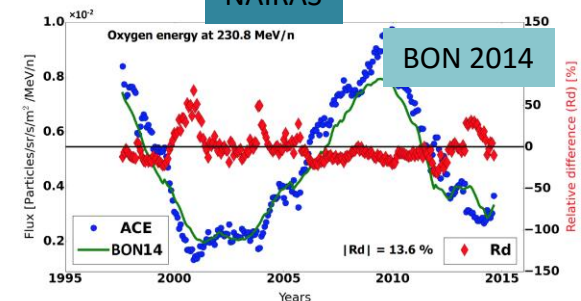
Modelers: , M. Xapsos, C. Martens, K.Copeland, P. O'Neill, S. Golge



HST from NOVICE



NAIRAS



CCMC: Y.Zheng



Assessment, Metrics & Validation

**Testing predictive
capability
before the event
onset**



**Forecasting
Methods
ScoreBoards**

Examples:

CME Arrival Prediction
Storm onsets
Flare Forecasts
SEP Forecasts

**Event-based M&V
to trace model
improvement**

[2003] 10/27 - 10/30
[2006] 12/13 - 12/16
[2010] 04/04 - 04/07
[2011] 08/05 - 08/07

.....
A list of events.
High quality data.
A library of metrics.

**Simulate the same set of
events over and over...**

Examples:

TEC, Neutral density,
Auroral boundaries,
Ground magnetic
perturbations dB/dt

**Sanity check Toolkit
for real-time runs**

**Sensitivity analysis
to external drivers and
internal parameters**

**Performance
evaluation for
extreme driving**

**Correlate forecasts
with impacts**

Testing Predictive Capabilities Before Event Onset

- Collecting and displaying event forecasts from multiple models & different sources in a **Scoreboard**
- Generate experimental international community-wide ensemble forecasts.
- Demonstrate operational potential to users.



CME Scoreboard

Lead: **L. Mays**, CCMC



Flare Scoreboard

Leads: **S. Murray**, Met Office
A. Devos, **J. Adries**, ROB



SEP Scoreboard (planning)

Leads: **M. Dierckxsens**, BIRA
M. Marsh, Met Office



Royal Observatory
of Belgium





CME Arrival Prediction Scoreboard

- Initiated in 2013
- There are currently **19 registered methods** predicting CME arrival time, including entries from the CCMC, Met Office, NOAA/SWPC, KSWC, ROB/SIDC
- Total CMEs in ScoreBoard: **108**

2016: 8 2015: 32 2014: 46 2013 (start in March): 22

CME: 2015-06-21T02:48:00-CME-001

Actual Shock Arrival Time: 2015-06-22T17:59Z

Observed Geomagnetic Storm Parameters:

Max Kp: 8.0

Dst min. in nT: -195

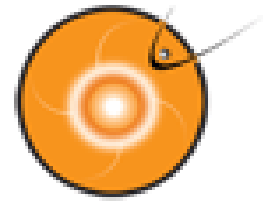
Dst min. time: 2015-06-23T05:00Z

CME Note: From near disk center, AR 12371. Associated with M-class flares.

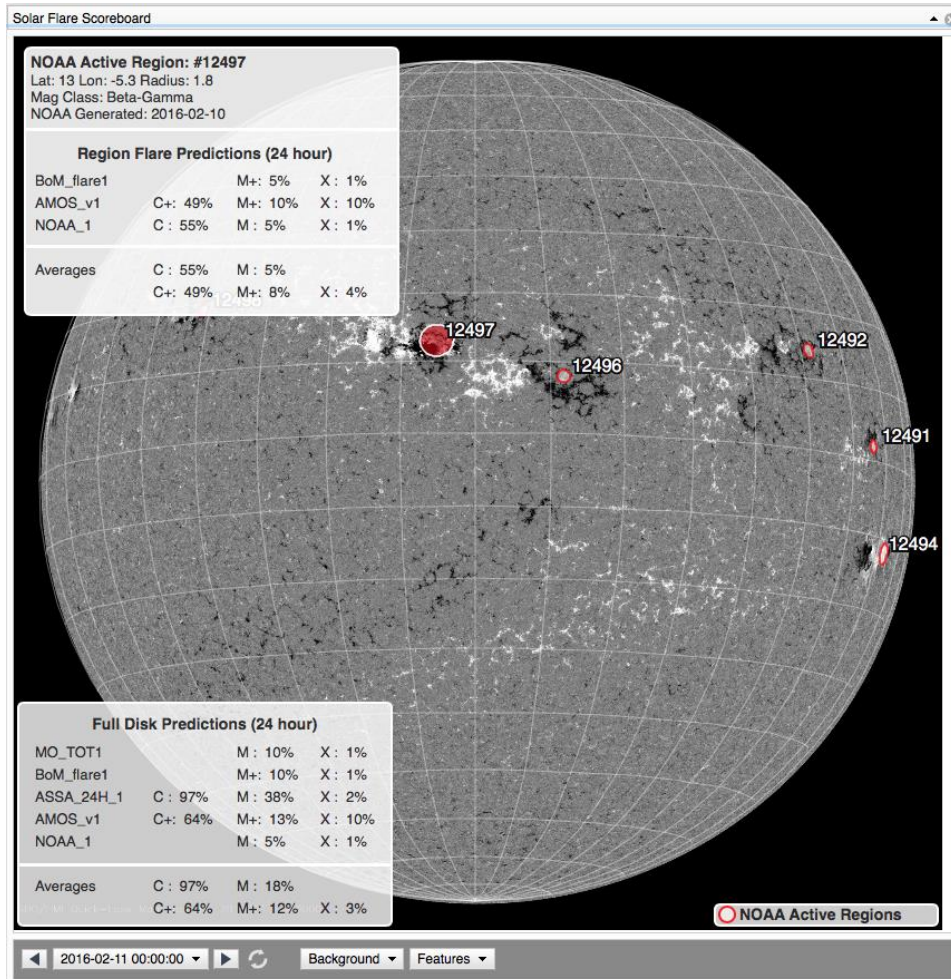
Predicted Shock Arrival Time	Difference (hrs)	Confidence (%)	Submitted On	Lead Time (hrs)	Predicted Geomagnetic Storm Parameter(s)	Method
2015-06-22T17:00Z (-12.0h, +12.0h)	-0.98	90.0	2015-06-21T10:26Z	31.55	Max Kp Range: 4.0 - 8.0	Other (SIDC)
2015-06-22T21:00Z	3.02	----	2015-06-22T01:00Z	16.98	Max Kp Range: 5.0 - 8.0	WSA-ENLIL + Cone (Met Office)
2015-06-22T21:43Z (-7.0h, +7.0h)	3.73	100.0	2015-06-22T03:25Z	14.57	Max Kp Range: 6.0 - 8.0	WSA-ENLIL + Cone (GSFC SWRC)
2015-06-22T19:03Z (-5.15h, +3.33h)	1.07	100.0	2015-06-22T03:32Z	14.45	Max Kp Range: 7.0 - 8.0	Ensemble WSA-ENLIL + Cone (GSFC SWRC)
2015-06-22T23:00Z (+7.0h)	5.02	100.0	2015-06-22T06:28Z	11.52	----	DBM
2015-06-22T22:50Z (-5.0h, +8.0h)	4.85	----	2015-06-22T09:20Z	8.65	----	ElEvo
2015-06-22T14:00Z	-3.98	----	2015-06-22T15:23Z	2.60	Max Kp Range: -- - 7.0	WSA-ENLIL + Cone (NOAA/SWPC)
2015-06-22T19:48Z	1.82	97.5	---	---	Max Kp Range: 5.5 - 7.8	Average of all Methods



Flare Scoreboard: Ensemble Solar Flare Forecasts



<http://ccmc.gsfc.nasa.gov/challenges/flare.php>



Activity initiated in Nov 2014

7 models,
more are coming

Beta live display
on iSWA



Australian Government
Bureau of Meteorology

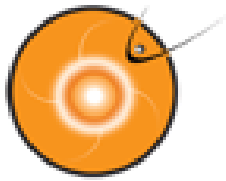


UNIVERSITY of
BRADFORD



Royal Observatory
of Belgium



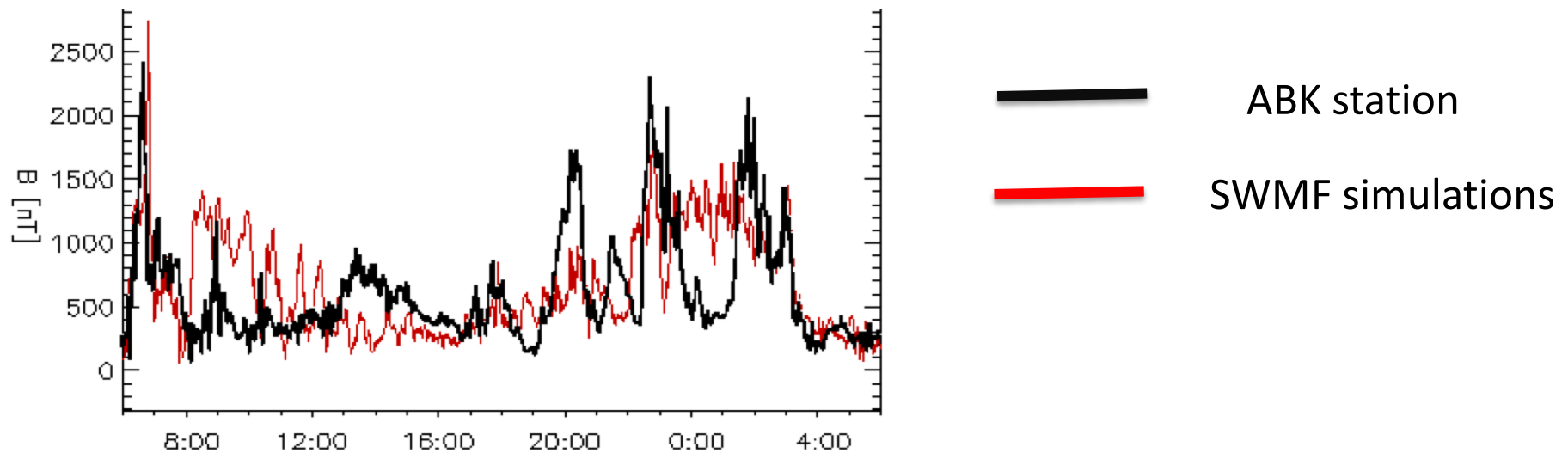


Assessmen, Metrics & Validation are Challenging Research Tasks

Example of discouraging & misleading Skill Scores

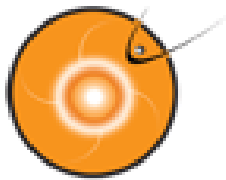
Metric study: Ground magnetic field perturbations

Event: October 29th, 2003 06 00 UT - October 30th, 06 00 UT



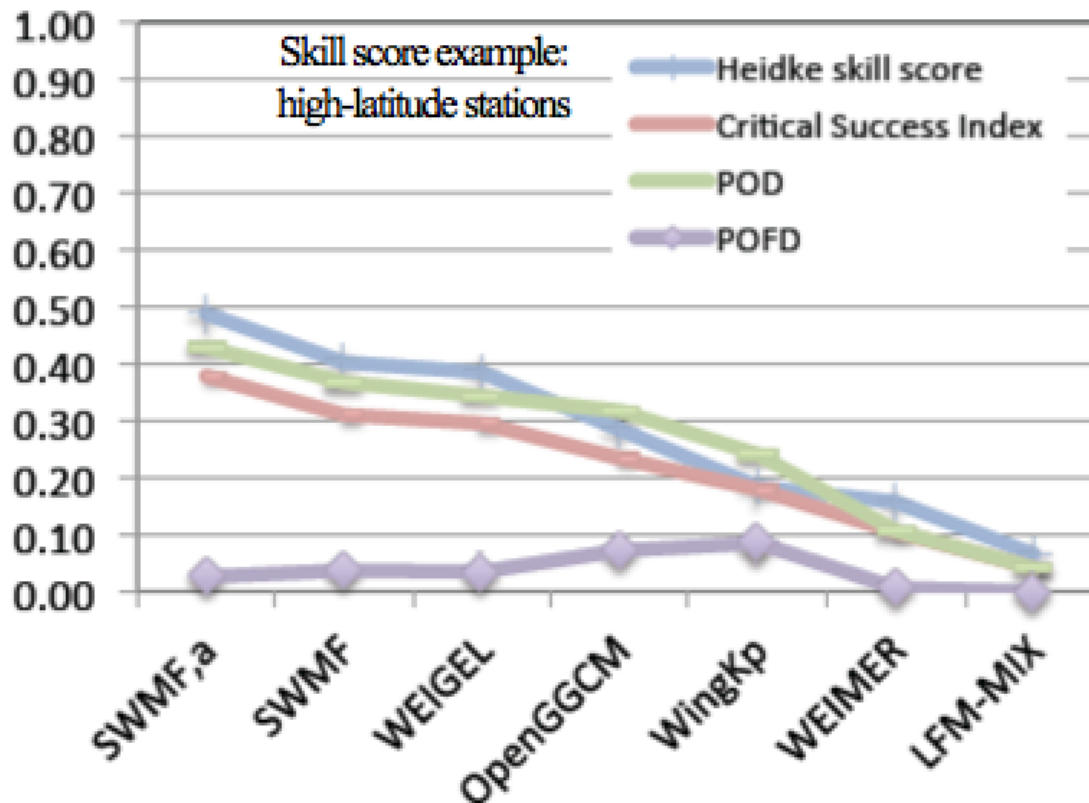
Negative Prediction Efficiency (based on RMS): **- 0.2**
(model performance is worse than “no perturbations” benchmark)

Metrics should reflect state-of-the-art and quantify useful information that can be derived from the model



Operational Geospace Model Validation in support of SWPC geospace model selection

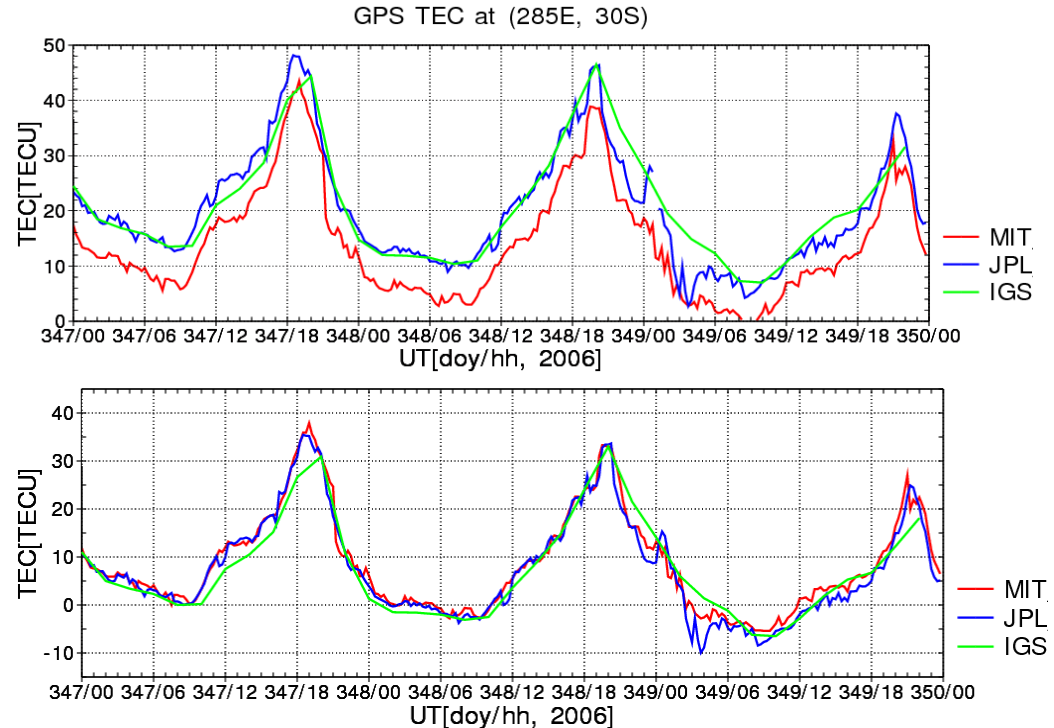
Example of Skill Score selection to validate **model ability to reproduce ground magnetic perturbations dB/dt**



6 events

Examples of M&V Challenges: Biases in TEC Measurements

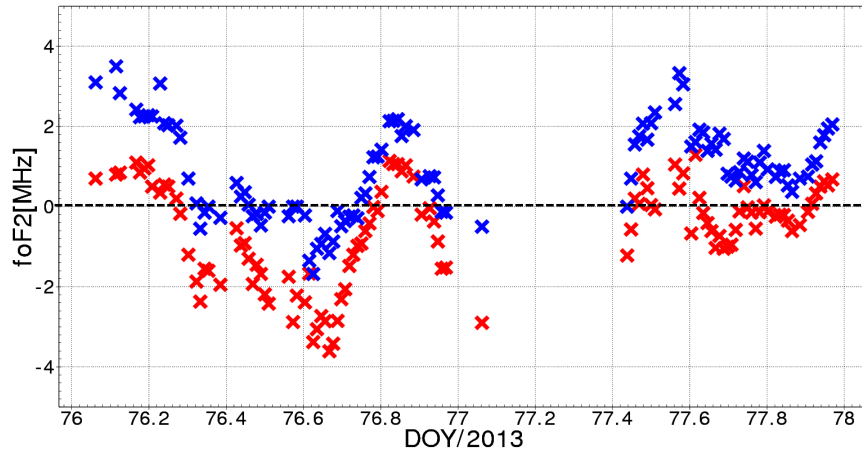
- Difference between GPS TEC data sets
- $\text{TEC} - \text{TEC}_{\text{quiet}}$



What is the best quiet
time reference?

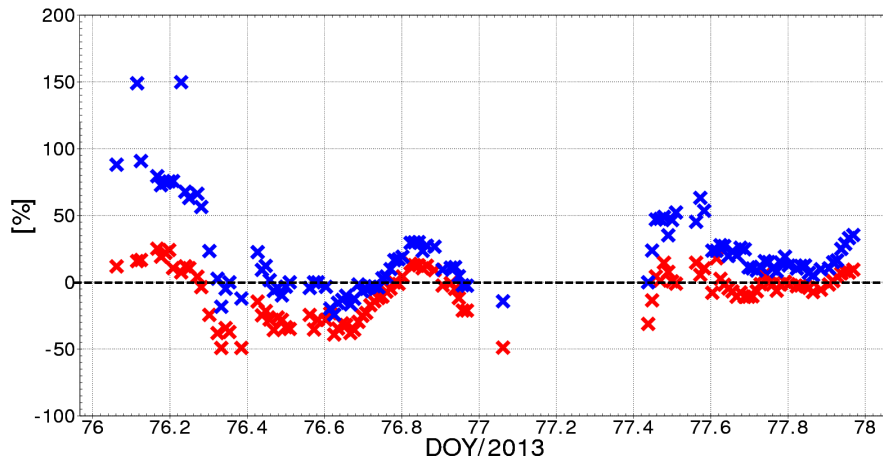
- TEC of one day prior to storm events
- median for the 30 days prior to storms

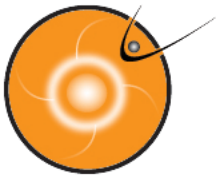
Ionospheric foF2 Critical Frequency at Millstone Hill March 2013 Storm (doy 076)



red: $\text{foF2} - \text{foF2}_{\text{quiet}} (\text{doy } 075)$

blue: $\text{foF2} - \text{foF2}_{\text{quiet}}$
(30-day median)





Outlook

- CCMC is
 - a fast response unit to emerging space weather community needs.
 - a hub for collaborative advancing of space weather prediction capabilities
 - an asset and resource for addressing objectives identified in National Space Weather Action Plan

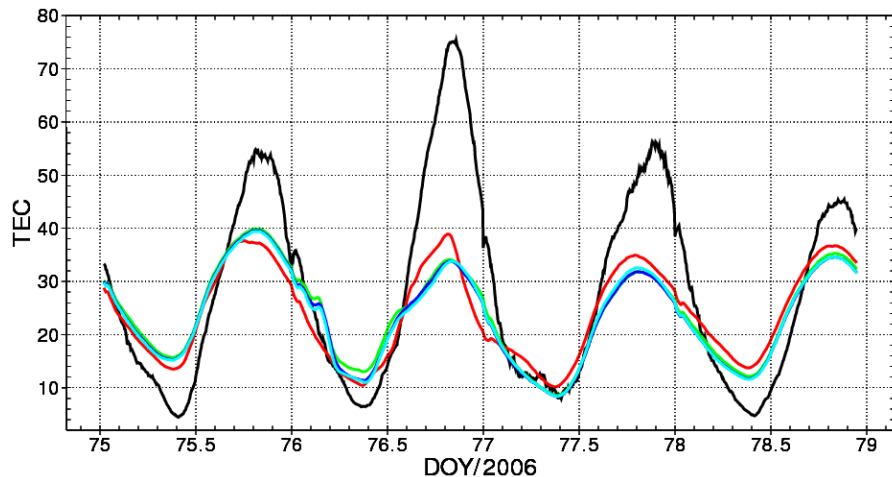
Supplementary material

Regional TEC over North American Sector

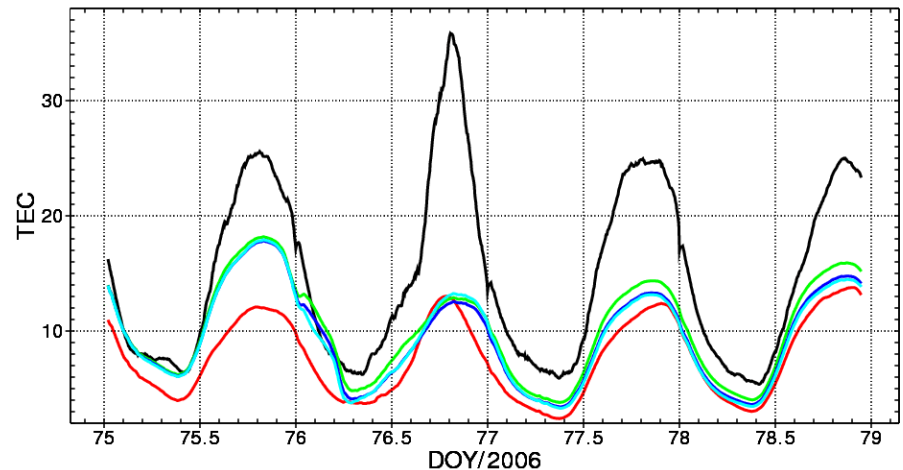
CTIPe driven by Enlil Cone Model

Ensemble Forecasts

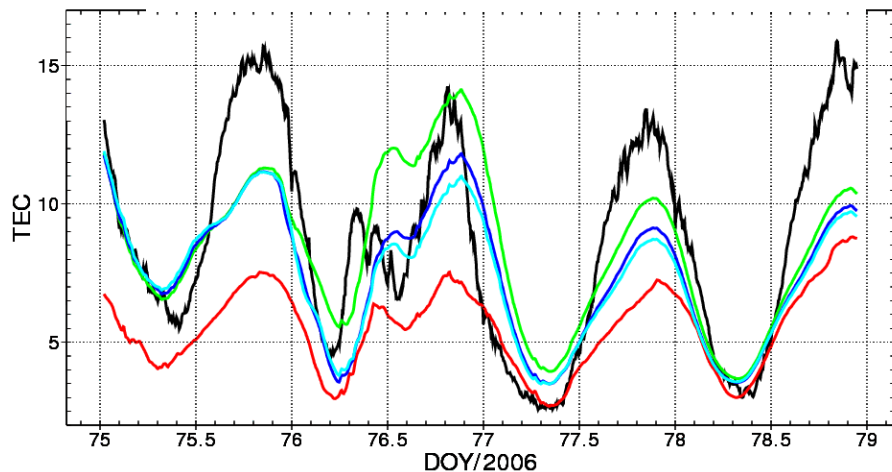
low lat ($0^\circ < \text{lat} < 25^\circ$)



middle lat ($25^\circ < \text{lat} < 50^\circ$)



high lat ($50^\circ < \text{lat}$)

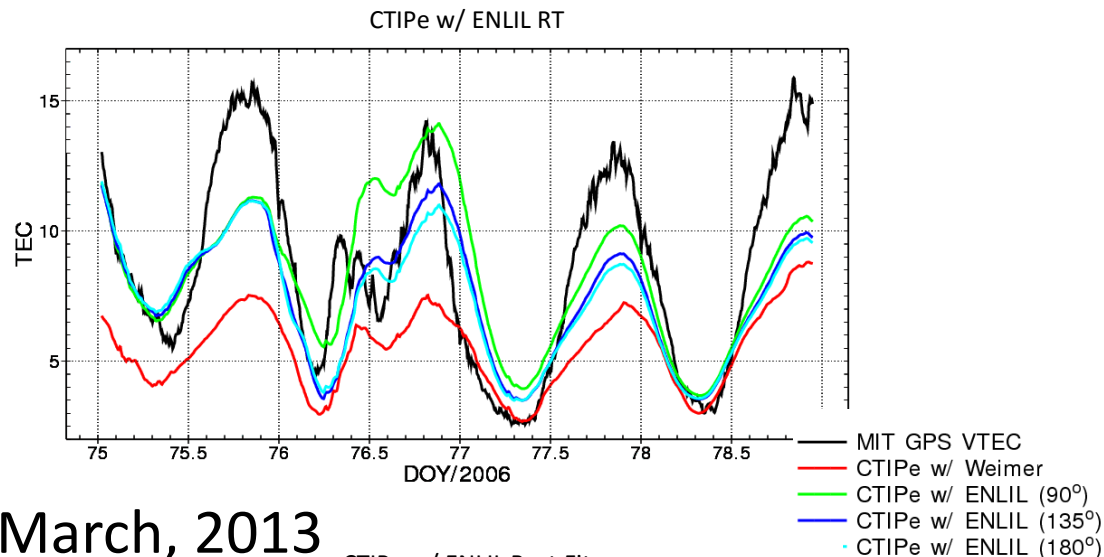
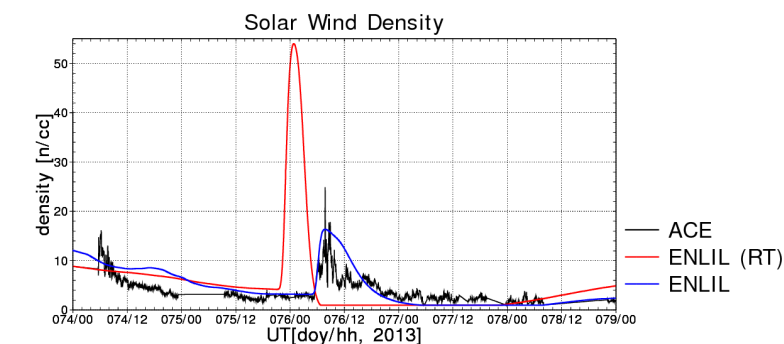
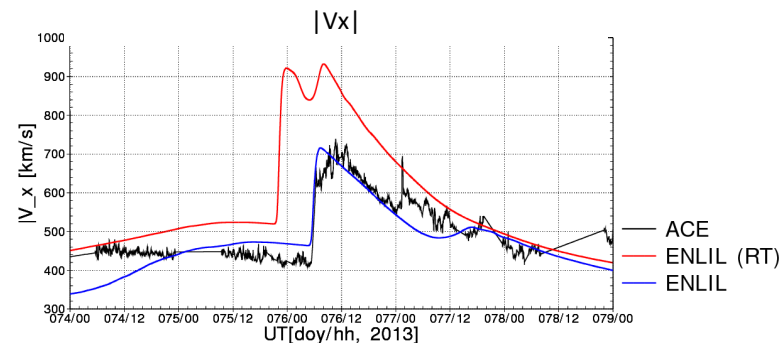
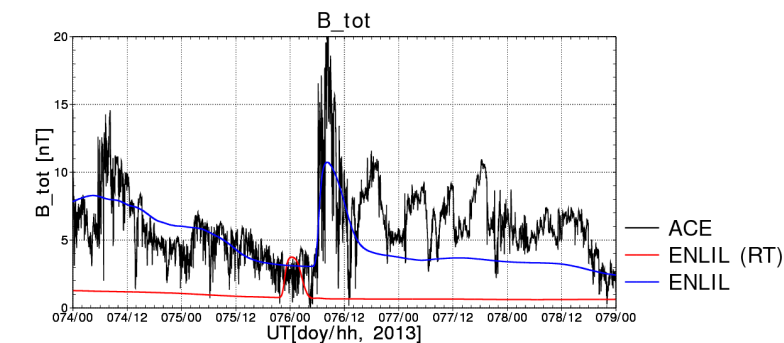


***IMF orientation
uncertainty impact on
regional TEC
at different latitudes.***

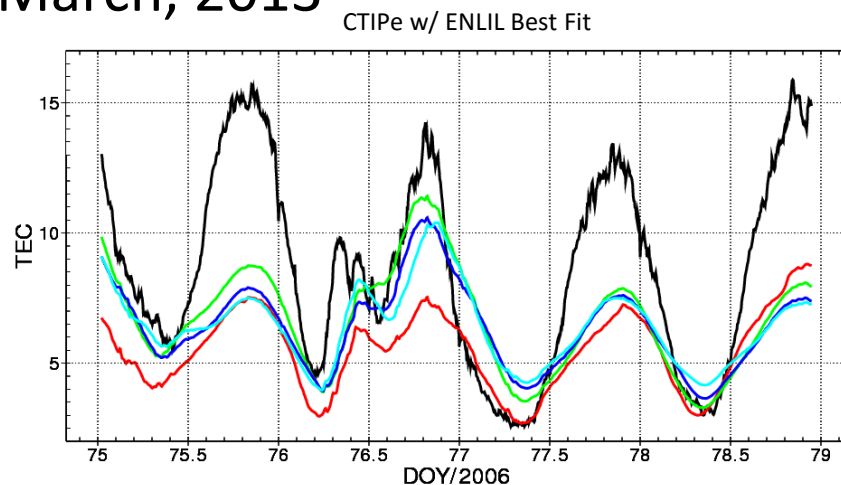
— MIT GPS VTEC
— CTIPe w/ Weimer
— CTIPe w/ ENLIL (90°)
— CTIPe w/ ENLIL (135°)
— CTIPe w/ ENLIL (180°)

March, 2013

Regional TEC over North American Sector Driven by Ensemble Enlil (Mean RT & Best Fit)



March, 2013



SRPM Irradiance Model

Status at CCMC

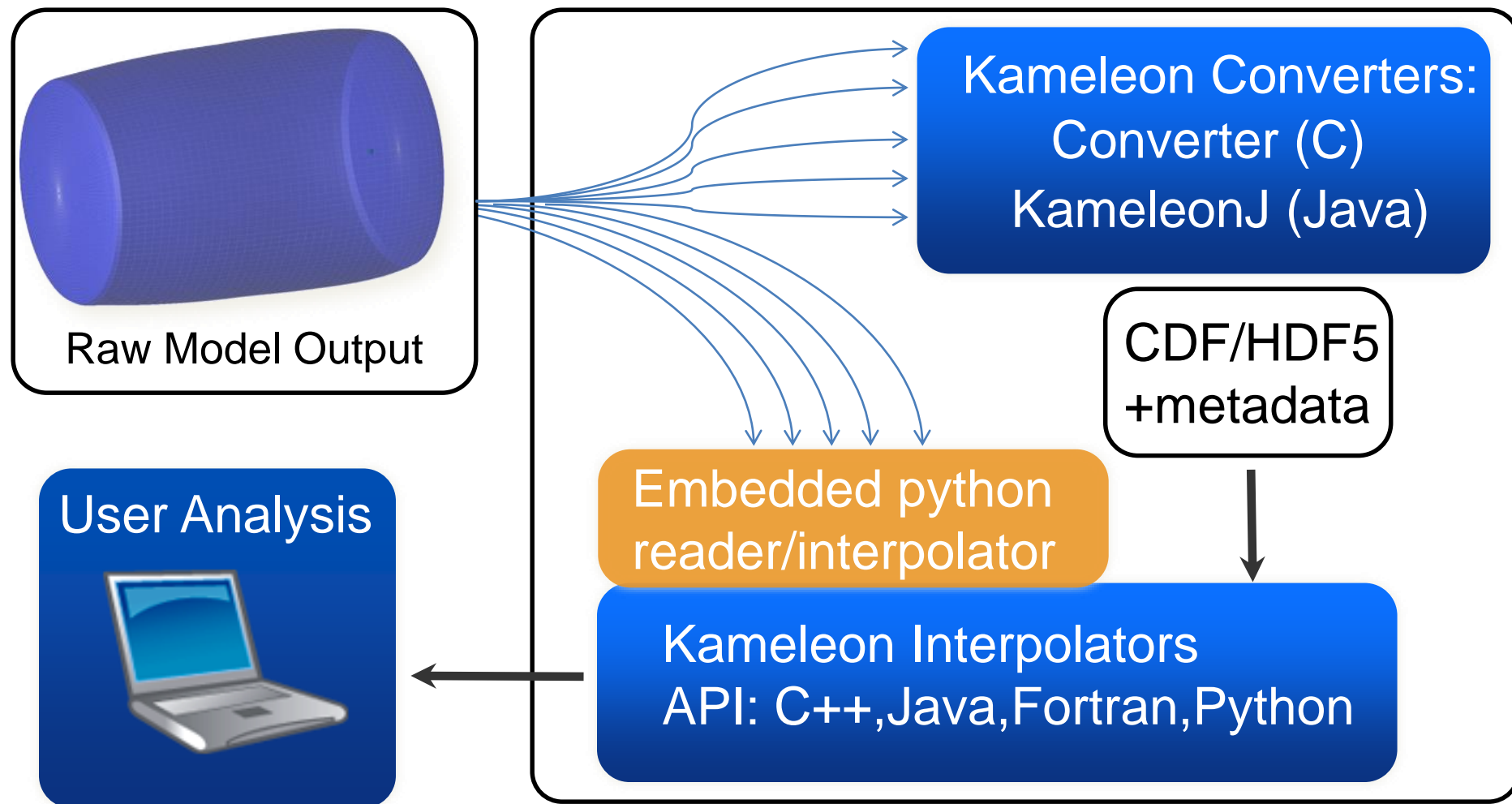
- Currently output EUV spectra between 1.8 and 200 nm with 1nm resolution
 - Most variable part of spectrum
- Posted at ISWA daily
 - iswa.gsfc.nasa.gov/iswa/iSWA.html
- Will extend to full spectrum in early 2016.
- Long term goals
 - Solar
 - ROR use – user supplied masks, customized resolution runs, archival runs etc
 - Stellar
 - Build ROR-like facility to generate irradiance spectra for use in modeling exoplanet atmospheres
 - Initially for solar like stars only
 - Later to support user modification to $\rho(r)$, $T(r)$ profiles of different feature types



Kameleon

Metadata, Standardization, Access, Interpolation

Goal: To facilitate access to space weather models hosted at the CCMC and enable scientific discovery.





CCMC Databases Re-Architecture Models, Simulations and Beyond

Objectives:

- Address a need for a hub for the community to easily search and obtain simulations data for their own research
- Enable easy model-data comparisons
- Enable easy linkage between different CCMC databases (RoR, iSWA, DONKI, ScoreBoard)
- Enable community to build a wide range of tools and front-end applications utilizing simulation data from CCMC

Status:

- Database design based on SPASE and IMPEx
- Web interface allowing to enter model information
- Web service interface allowing applications to obtain model information (JSON format)